SECTION II.—GENERAL METEOROLOGY.

SOLAR DISTURBANCES AND TERRESTRIAL WEATHER.

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(*Continued from* this Review, March, 1918, p. 141.)

II. Sunspots Compared With Changes in the Weather.

Solar quadrant differences compared with changes of barometric gradients for all days during 1904–1913.

The first article of this series led the writer to the conclusion that storminess in the North Atlantic Ocean is closely associated with differences in the amount of spottedness upon different portions of the sun's surface. It appeared that during the years 1904–1909 pronounced barometric disturbances occurred when the spottedness of the marginal portions of one pair of diametrically united solar quadrants greatly exceeded the spottedness in the other pair of quadrants. One of the best tests of this conclusion is to reverse the order of procedure. Instead of proceeding from the earth to the sun, let us start with the supposed solar cause and compare it with the supposed result. For the sake of varying our terrestrial data we may this time use neither the absolute strength of the barometric gradients, nor their increase or decrease, but their change from day to day, no matter in which direction. Judging from figures 5 and 6 (pp. 129,130) this method will perhaps not give such striking results as if increase of gradients were used for the northern part of the North Atlantic and decrease for the southern. On the other hand, by using the change in gradients we employ perhaps the best of all means of measuring the total variability of the weather. For the solar data we use the quadrant differences as already defined—that is, the difference between the sum of [A+D] (fig. 3) and the sum of [B+C] without regard to which of the two sums is larger.

Let us first divide all the days of the 6-year period 1904–1909 into groups on the basis of the quadrant differences in the sun. As appears in Table 6, group A consists of 653 days having a quadrant difference of 10 or less, group B of 284 days with a difference of 11 to 20, and so up to group H, consisting of 156 days, with a difference of over 150. If these solar differences are really responsible for changes in the weather, we should expect the daily change in gradients to increase from group A to group H. The extent to which this is the case is shown in figure 9. Here the height of the curves above the zero line at the bottom indicates the degree of variability of the weather. The distance from left to right indicates the solar activity in terms of the difference between the sunspot areas in the marginal portions of the two pairs of diametrically united quadrants. If our hypothesis is right the curves ought to rise from left to right.

In figure 9 the upper dash lines represent the barometric variability of the southern section of the North Atlantic. Below these come solid lines representing the average for both sections of the Atlantic, and dotted

Table 6.—*Changes in barometric gradients of all days, March, 1904, to December, 1909, compared with solar quadrant differences (see fig. 9).*

[N=Sum of changes of gradient in northern section of North Atlantic; S=Sum of changes of gradient in southern section of North Atlantic.]

Quadrant difference.	A, 0-10.			B, 11-20.			C, 21-30.			D, 31-50.			E, 51-75.			F, 76-100.			G, 101-150.			H, over 150.		
Year.	Days.	N.	S.	Days.	N.	S.	Days.	N.	S.	Days.	N.	S.	Days.	N.	S.	Days.	N.	S.	Days.	N.	S.	Days.	N.	S.
1904	111	1,630	2,186	65	1,074	1,067	31	365	563	39	462	612	28	440	530	16	173	268	10	213	197	6	117	70
1905	82	1,275	1,288	36	524	754	35	545	577	49	748	882	49	841	963	32	518	819	37	632	635	44	888	900
1906	122	1,877	2,449	39	601	698	33	541	594	54	861	964	50	726	825	29	560	508	26	525	455	12	167	171
1907	80	1,366	1,550	51	819	853	36	587	600	35	572	572	54	954	937	27	318	590	29	491	410	53	1,183	1,171
1908	126	2,096	2,300	50	894	818	33	477	541	59	943	1,200	43	774	768	22	313	288	18	303	308	15	192	190
1909	132	2,136	2,065	43	643	925	38	573	699	37	633	761	34	612	612	30	337	782	25	300	598	26	411	427
Total	653	10,380	11,838	284	4,555	5,115	206	3,088	3,574	273	4,219	4,991	258	4,347	4,635	156	2,219	3,255	145	2,464	2,603	156	2,958	2,929
Average	......	15.9	18.2	......	16.0	18.1	......	14.9	17.3	......	15.5	18.3	......	16.8	18.0	......	14.2	20.8	......	17.0	18.0	......	18.9	18.8

Table 7.—*Changes in barometric gradients of all days, March, 1904, to December, 1913, compared with average solar quadrant differences for the period of four days ending with the day of the observed change of gradient (see fig. 9).*

[N=for northern section of North Atlantic Ocean; S=for southern section of North Atlantic Ocean.]

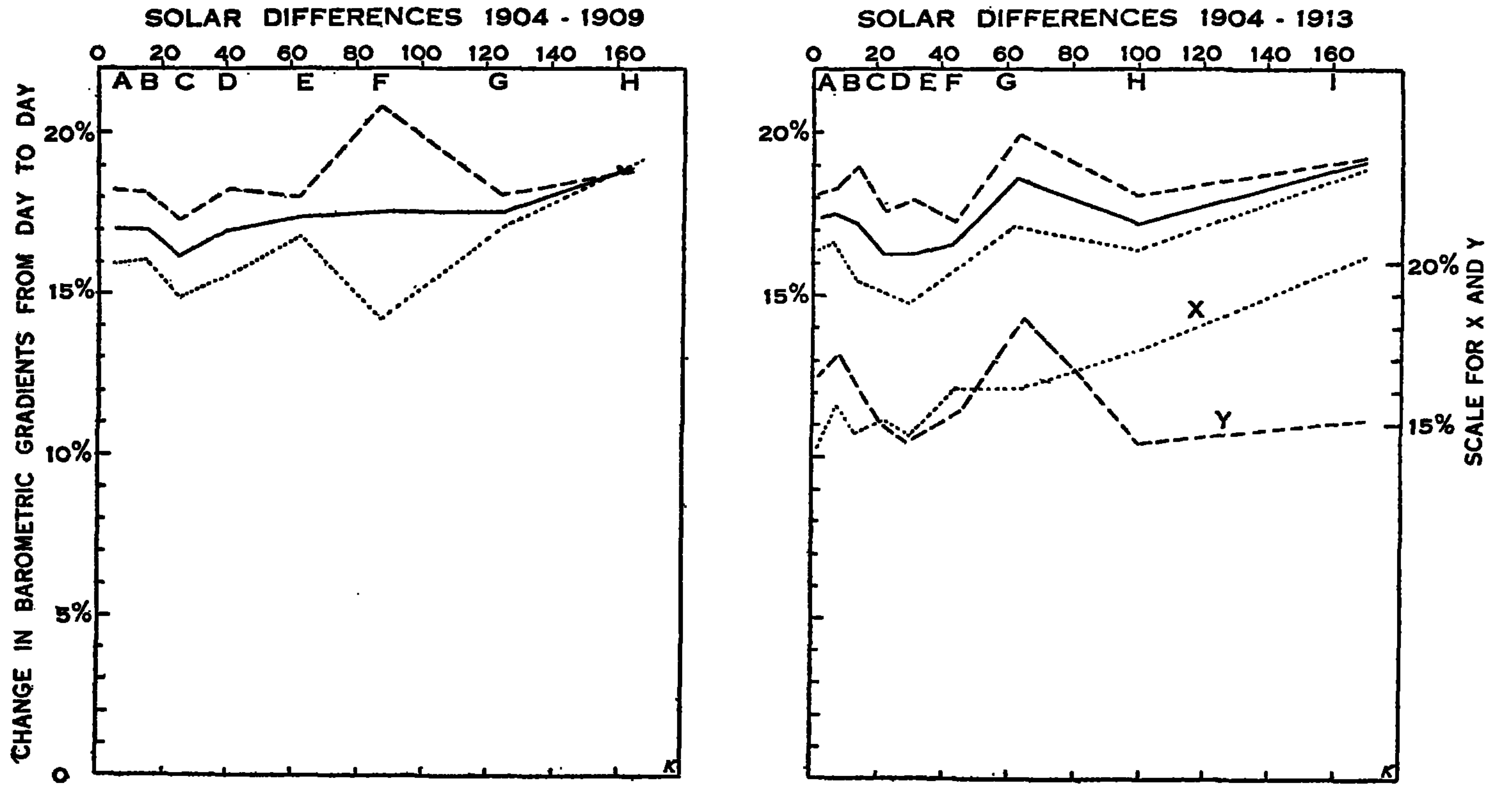
Quadrant difference.	A, 0-5.			B, 6-10.			C, 11-17.			D, 18-25.			E, 26-37.			F, 38-50.			G, 51-75.			H, 76-125.			I, over 125.		
Year.	Days.	N.	S.	Days.	N.	S.	Days.	N.	S.	Days.	N.	S.	Days.	N.	S.	Days.	N.	S.	Days.	N.	S.	Days.	N.	S.	Days.	N.	S.
1904	43	607	709	36	525	671	50	776	971	52	851	750	45	653	897	28	355	518	30	411	609	17	266	251	5	134	136
1905	11	128	135	17	228	296	22	294	479	37	512	630	53	985	943	50	802	863	56	935	1,263	62	1,020	1,152	56	997	1,121
1906	39	502	809	25	388	531	48	783	1,119	32	486	526	61	786	1,059	44	729	759	61	1,093	1,087	46	918	767	8	112	136
1907	11	250	139	23	431	459	33	404	506	27	380	458	51	853	836	36	660	567	68	1,029	1,506	60	995	1,105	57	1,307	1,153
1908	39	671	732	35	625	666	54	905	1,005	33	409	577	62	1,019	1,083	38	521	682	69	1,475	1,170	21	305	328	15	199	126
1909	35	581	534	36	587	551	43	749	790	43	586	713	51	647	1,101	36	639	626	52	861	1,182	39	555	878	30	479	532
1910	129	2,092	2,393	34	582	729	36	637	491	47	734	1,039	43	524	776	27	450	474	32	534	588	14	192	193	5	58	90
1911-1913	898	14,894	16,311	73	1,264	1,201	50	631	1,007	27	499	515	31	532	564	9	76	152	6	44	73	1	16	18	0	0	0
Total for 1904-1913	1,205	19,725	21,762	279	4,630	5,104	336	5,179	6,368	298	4,458	5,208	407	5,999	7,259	268	4,232	4,641	374	6,382	7,478	260	4,267	4,692	171	3,228	3,294
Average for 1904-1913	......	16.4	18.1	......	16.6	18.3	......	15.4	19.0	......	15.0	17.5	......	14.7	17.9	......	15.8	17.3	......	17.1	20.0	......	16.4	18.0	......	18.9	19.2

lines for the northern section. According to these lines barometric variability appears to be greater in the southern section of the North Atlantic than in the northern. As already explained, however, this is merely because the figures for gradients have been reduced to percentages. In the left-hand part of figure 9 one of the first features to attract the eye is the marked rise of one curve and fall of the other between 80 and 100. This means that during the group of days marked F there happened to be an unusual number of storms with courses more southerly than the normal. They caused unusually great changes in the weather in the southern section of the North Atlantic where high pressure generally prevails, while the northern section was unusually free from such changes. This is significant because it indicates that if it were possible rigidly to separate areas of high and low pressure our solar relationships would appear more distinct than is now the case.

Taking the lines in the left-hand part of figure 9 separately and disregarding the minor fluctuations, we see that aside from the point *F* the dash line representing the variability of the weather in the southern section has a slight tendency to rise from left to right. The average change of gradients from day to day in groups A to D is 18 per cent while in groups E to H it is 18.9 per cent. In the northern section, as appears in the dotted line, the rise from left to right is greater, being from 15.6 in groups A to D to 16.7 in groups E to H. Except for an accidental depression in group C, the combined line for the two sections rises rather steadily from 17 at the left end (group A) to 18.9 on the right (group H). Thus there is evidence that the greater the solar difference the greater the variability of the weather in the North Atlantic Ocean. This is especially true in the northern section, for there the variability in group A is only 15.9 while in group H it is 18.9, a difference of 19 per cent.

If instead of group H, which includes 156 days having quadrant differences of over 150, we take a smaller group of 87 days with quadrant differences of over 200, the average variability from day to day in the northern section of the North Atlantic rises from 18.9 to 19.1. This is 18 per cent above the general average, which is 16.2, and 20 per cent above group A. Among the 87 days of the group with largest quadrant differences, 43 show an increase in gradients, averaging 18.8, while 44 show a decrease averaging 19.4.

If a difference in the solar quadrants for only a single day produces a terrestrial effect, a continuance of such a difference would presumably produce a greater effect. Therefore in Table 7 and in the right-hand part of figure 9 all the days from 1904 to 1913 are classified into 9 groups according to the average difference in the solar quadrants during the period of 4 days ending with the day in question. In group A this average quadrant difference is 5 or less, in group B, 6 to 10, and so on up to group I where the average differences are over 125. In spite of considerable irregularity the three upper lines in the right-hand part of figure 9 show a stronger upward tendency from left to right than do the corresponding lines in the left-hand part of the diagram. Years of many and few sunspots, however, by no means act alike. This is evident from lines *X* and *Y* in figure 9. Line *X* pertains to the years 1904–1907 when sunspots were *increasing*. Line *Y* pertains to 1908–1913 when sunspots were *decreasing*.



. . . , changes in gradients in north section of North Atlantic Ocean, 1904–1909.
— — —, changes in gradients in south section of North Atlantic Ocean, 1904–1909.
———, average of . . . and — — —

X, changes in northern section, 1904–1907, when sunspots were abundant or increasing.
Y, changes in northern section, 1908–1913, when sunspots were scarce or decreasing.

FIG. 9.—Changes in barometric gradients from one day to the next, in relation to days having varying differences between the areas of the umbræ in the NW.+SE. quarters of the sun's visible disk, at a distance of more than 30° from the central meridian and in the NE.+SW. quarters.

The zero point of X and Y, it will be noted, has been placed lower than that of the other lines in order to avoid overlapping. Curve X has a pronounced upward tendency. The right-hand end is more than 30 per cent higher than the left, and the irregularities are small. Curve Y on the other hand, scarcely shows any distinct tendency either upward or downward. The average of groups A to E, to be sure, is 15.22, while that of F to I is 15.75. Nevertheless, here, just as in a previous case, we are confronted by what seems to be a contradiction; in general the greater the solar differences the greater the barometric disturbances, but when the sun's surface becomes unusually quiet this generalization breaks down.

This apparent anomaly is similar to one found by Arctowski[1] in studying the relation of the solar constant to the number of sunspots. For all the years for which Abbot's solar constants were available at the time of writing, Arctowski divided the days having reliable solar observations into groups of 10 arranged according to the intensity of the constant. He then compared the average constants for each group with the average areas of the solar umbræ for the same 10 days. I have combined his 10-day periods into two groups for each year as appears in Table 8. The groups are as nearly equal as possible. The one marked A in each case contains the days having the lowest constant and B the highest.

TABLE 8.

Year.		Solar constant.	Area of umbræ.	Year.		Solar constant.	Area of umbræ.
1905	A	1.99	212	1909	A	1.88	96
	B	2.06	246		B	1.95	59
1906	A	1.99	133	1910	A	1.89	64
	B	2.04	207		B	1.94	52
1907	A	1.92	122	1911	A	1.90	7
	B	1.96	170		B	1.95	5

In 1905, 1906, and 1908, when sunspots were numerous, an increase in spottedness and in the solar constant occurred together, for B in each case is larger than A. In 1909, however, we find a sharp reversal. In the column of umbræ B is smaller than A. Similar conditions continue in 1910 and 1911.

This anomaly is probably of the same kind as that which we have found in the relation between quadrant differences and changes in barometric gradients. Apparently sunspots are not in themselves the cause either of an increase in the sun's thermal radiation, or of a change in the barometric conditions of the earth. All three are apparently merely the results of some other cause. Suppose for the moment that the primary cause of variations (1) in the solar constant, (2) in the area of sunspots, and (3) in terrestrial storms is the eruption of intensely heated gases or vapors from the lower part of the sun's atmosphere. This, we will suppose, is followed by the formation of vaporous clouds which at first appear as bright faculæ, but later become relatively cool and dark, and are sucked downward in the vortices known as sunspots. We will assume further that at such times the solar constant varies in harmony with the area of the sunspots, and the disturbances of terrestrial weather show a similar variation. Suppose, however, that the circulation of solar vapors is relatively mild. It might easily happen that the clouds of vapor would be so thin that we could not detect them, and that the downward movements would not be sufficiently concentrated to form visible dark spots. Yet the observed changes in the solar constant and in the weather might go on. Thus variations in both the solar constant and the weather may be closely associated with sunspots when the sun's surface is highly active, but may also arise from the same causes even when there are no visible signs of such activity.

Comparison of extreme solar disturbances with North Atlantic gradients.

From this brief excursion into the realm of theory let us turn back to actual facts of observation. Let us test various methods in order to see how far the method of quadrant differences is justified. We will inquire first what happens on the earth for 8 days before and 8 days after the periods when the quadrant differences and several other types of solar phenomena are at their height. Such an inquiry is illustrated in Table 9 and figures 10 to 14. The height of the curves indicates the degree of variability from day to day. The time when a given condition prevails is shown by the numbers at the top or bottom. The "days of solar disturbance" are of many types. All alike include all the days of their particular type in the 10 years, 1904–1913. It so happens, however, that owing to the small sunspot numbers of the years 1911–1913, no days from 1911 and 1913 and only one or two from 1912 enter into any of these diagrams. The days of disturbance may occur singly, or more often in periods of two, three, or in rare cases, six or seven days. The interval between two such periods may be anywhere from one day upward. Only about 30 per cent of the time does the interval between the end of one period and the beginning of another amount to 16 days or more. Hence only in this proportion is it possible to carry the figures to the full limit of eight days before the beginning of a disturbance and eight days after the end without repeating one or more days. Such repetition not only would give the days in question undue weight, but would cause days which are influenced by the specified solar conditions to be reckoned as if they came before such conditions, as well as during or after them. Hence in preparing Table 9 it has been necessary to adopt a somewhat complicated method which can best be understood from the following example:

Example illustrating method of preparing Table 9.

Date.	Days before.								Days of solar disturbance.								Days after.							
	8	7	6	5	4	3	2	1	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8
1905.																								
June 28	45	21	44	4	3	9	7	1	30	2	40	..	..	..	..	..	4	29	17	2	10	..	..	..
July 10	..	..	..	..	16	2	11	4	20	27	8	2	15	21	33	..	15	8	..	..	..	..	..	..
July 19	..	..	..	..	..	..	..	..	43	4	59	33	45	..	..	..	1	8	12	11	14	0	24	3

June 28, 1905, was the first day of a quadrant difference of over 100. The change in the gradient index in the northern section of the North Atlantic from June 27 to June 28 amounted to 30 per cent of the normal gradient for that date. Hence the number 30 is recorded opposite June 28 under the first "day of solar disturbance." The next two days were also marked by quandrant differences of over 100. Hence their changes of gradients. 2 per cent and 40 per cent, are recorded under the second and third days of solar disturbance.

[1] *Arctowski, H.* Sur les fluctuations de la constante solaire. Comptes rendus, t. 163: 665.

Previous to June 28 there were no strong quadrant differences for some time. Hence it is possible to record the "days before" to the full number of 8. The first "day after" the end of the solar disturbance was July 1, with a change in gradients of 4 per cent. Beginning with this day we have a series of 9 days falling between the end of one solar disturbance and the beginning of another. These are divided so that 5 fall among the "days after" and 4 among the "days before." With July 10 we enter upon a disturbed period of unusual length.[2] Between the end of this disturbance and the beginning of that of July 19 only two days intervene. These days are presumably influenced by the conditions of the preceding period of solar disturbance. They can scarcely be influenced by the solar disturbance that comes after them. Hence they are reckoned as the first and second days after a disturbance, and all the days before the disturbance of July 19 are left blank. The same method is followed whenever the number of days between the disturbances is 4 or less. If the number is from 5 to 8, however, the days beyond 4 are reckoned as preceding the second solar disturbance.

The net result of this method is that we have in the center a group of days which are unmistakably under the influence of strong solar disturbances. On either side we have days which are not so much under that influence. They are by no means free from it, however, for disturbances do not begin and end suddenly. Moreover, at intervals of 10 or more days before and after the beginning of solar disturbances, as has already been explained, there are almost sure to be other disturbances due to the fact that the disturbing groups of sunspots reach an effective position first on the sun's eastern margin and then on the western. Hence, even if quadrant differences were the only cause of barometric differences, we should not expect barometric variability to fall to a low ebb during the days before and after the times of solar disturbances.

There are other and stronger reasons why the barometric variability does not fall to a low ebb at times when quadrant differences in the sun are small. One of these is the fact that when a barometric disturbance has once arisen, no matter what the cause, it often persists many days and travels long distances. Thus a disturbance which arises thousands of miles away may be felt in the Atlantic Ocean one or two weeks later. Another important consideration is that variations in the sun's heat, as measured by the solar constant, also

TABLE 9.—*Changes in barometric gradients in relation to solar differences, 1904–1913.*

[N=northern section of North Atlantic. S=southern section of North Atlantic.]

A. IN RELATION TO 138 PERIODS WHEN THE QUADRANT DIFFERENCE EXCEEDS 100. (See Fig. 10.)

	Days before.								Days of solar disturbance.								Days after.							
	8	7	6	5	4	3	2	1	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8
Number of days	39	47	49	55	63	67	74	90	138	82	58	34	11	2	1	0	138	120	107	101	61	54	50	44
Average change of gradients N	18.4	18.3	17.5	14.2	15.4	15.2	16.3	14.0	16.5	16.2	21.6	19.1	18.8	14.5	33.0	......	17.3	15.3	16.1	17.2	14.1	14.5	16.9	15.2
Average change of gradients S	17.1	19.3	18.8	19.6	19.1	19.3	17.4	19.2	17.5	17.9	20.3	19.8	11.1	24.0	44.0	......	19.8	17.0	18.5	19.5	20.6	17.5	17.9	16.1

B. IN RELATION TO 144 PERIODS WHEN THE DIFFERENCE BETWEEN THE UMBRAL AREA ON THE EAST SIDE OF THE SUN WITHIN 60° OF THE MARGIN AND ON THE WEST SIDE WITHIN 60° OF THE MARGIN, EXCEEDS 100.

	Days before.								Days of solar disturbance.								Days after.							
	8	7	6	5	4	3	2	1	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8
Number of days	35	38	44	51	59	62	69	90	144	96	63	43	14	3	2	1	144	125	114	102	55	49	42	36
Average change of gradients N	17.2	15.4	15.8	14.7	16.6	14.5	14.5	15.2	16.9	15.0	20.4	16.1	20.1	18.7	15.0	24.0	16.6	16.2	16.2	14.8	16.2	14.6	17.9	17.3
Average change of gradients S	17.4	17.0	20.6	20.7	18.9	20.0	17.8	18.9	17.9	19.1	19.8	22.6	9.9	7.7	16.0	16.0	17.1	17.1	19.8	18.6	16.9	18.2	18.2	14.4

C. IN RELATION TO 110 PERIODS WHEN THE UMBRAL AREA WITHIN 30° OF THE SUN'S CENTRAL MERIDIAN EXCEEDS 100. (See Fig. 13.)

	Days before.								Days of solar disturbance.								Days after.							
	8	7	6	5	4	3	2	1	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8
Number of days	40	48	52	56	66	71	78	81	110	82	64	53	30	8	5	5	110	98	90	86	64	54	50	45
Average change of gradients N	15.4	15.6	15.9	16.5	16.3	17.2	15.2	16.2	16.5	16.4	16.8	16.2	13.9	12.1	8.6	6.6	15.8	14.5	19.7	15.7	17.0	19.2	16.0	15.8
Average change of gradients S	20.3	15.3	21.6	22.3	18.3	20.8	20.6	19.6	19.0	14.4	18.9	15.9	13.3	10.3	15.4	14.4	16.6	18.0	18.5	18.5	18.1	19.9	20.0	22.0

D. IN RELATION TO 53 PERIODS HAVING AN UMBRAL DIFFERENCE OF OVER 100 BETWEEN THE AREAS NORTH AND SOUTH OF THE SUN'S EQUATOR AND WITHIN 60° OF THE SUN'S MARGIN, BUT HAVING A QUADRANT DIFFERENCE OF LESS THAN 100.

	Days before.								Days of solar disturbance.								Days after.							
	8	7	6	5	4	3	2	1	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8
Number of days	34	35	36	38	42	44	47	48	53	19	10	6	......	......	......	......	53	51	51	50	41	37	35	34
Average change of gradients N	16.9	18.1	14.6	15.1	19.2	14.4	17.1	14.5	15.4	12.3	14.5	16.0	......	......	......	......	17.3	16.7	19.9	15.5	16.4	18.1	16.3	14.6

E. IN RELATION TO 79 PERIODS HAVING AN UMBRAL AREA OF OVER 100 IN THE COMBINED EAST AND WEST SECTIONS OF THE SUN WITHIN 60° OF THE MARGIN, BUT HAVING A QUADRANT DIFFERENCE NOT EXCEEDING 50.

	Days before.								Days of solar disturbance.								Days after.							
	8	7	6	5	4	3	2	1	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8
Number of days	28	31	31	34	39	46	48	56	79	24	10	2	......	......	......	......	79	67	66	60	38	32	31	31
Average change of gradients N	12.9	16.9	16.7	17.8	21.5	14.7	16.2	14.6	16.5	16.7	20.5	17.5	......	......	......	......	15.8	13.4	16.3	18.6	17.1	18.5	19.0	15.7

F. IN RELATION TO 159 PERIODS WHEN THE DIFFERENCE BETWEEN THE UMBRAL AREAS WITHIN 60° OF THE SUN'S MARGIN IN THE NORTHERN HEMISPHERE PLUS THE DIFFERENCE BETWEEN SIMILAR AREAS IN THE SOUTHERN HEMISPHERE, AMOUNTS TO 100 OR MORE.

	Days before.								Days of solar disturbance.								Days after.							
	8	7	6	5	4	3	2	1	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8
Number of days	36	40	46	51	61	69	76	94	159	108	82	56	24	8	4	1	159	138	125	114	57	48	43	37
Average change of gradients N	17.1	14.2	14.4	16.0	17.0	15.4	14.2	13.9	16.4	15.9	18.6	16.4	18.8				16.4	15.7	17.4	16.9	14.7	13.5	18.7	13.8

[2] Such periods are so rare that in plotting the results of this tabulation in lines *A* to *C*, figs. 10 and 14, all days from the sixth onward are reckoned with the fifth, while in lines *D* and *E* of fig. 10 all from the fourth onward are reckoned with the third. In fig. 11 the sixth, seventh, and eighth are reckoned as a separate group, while in fig. [illegible] all from the fifth to the eighth [illegible] reckoned with the fourth.

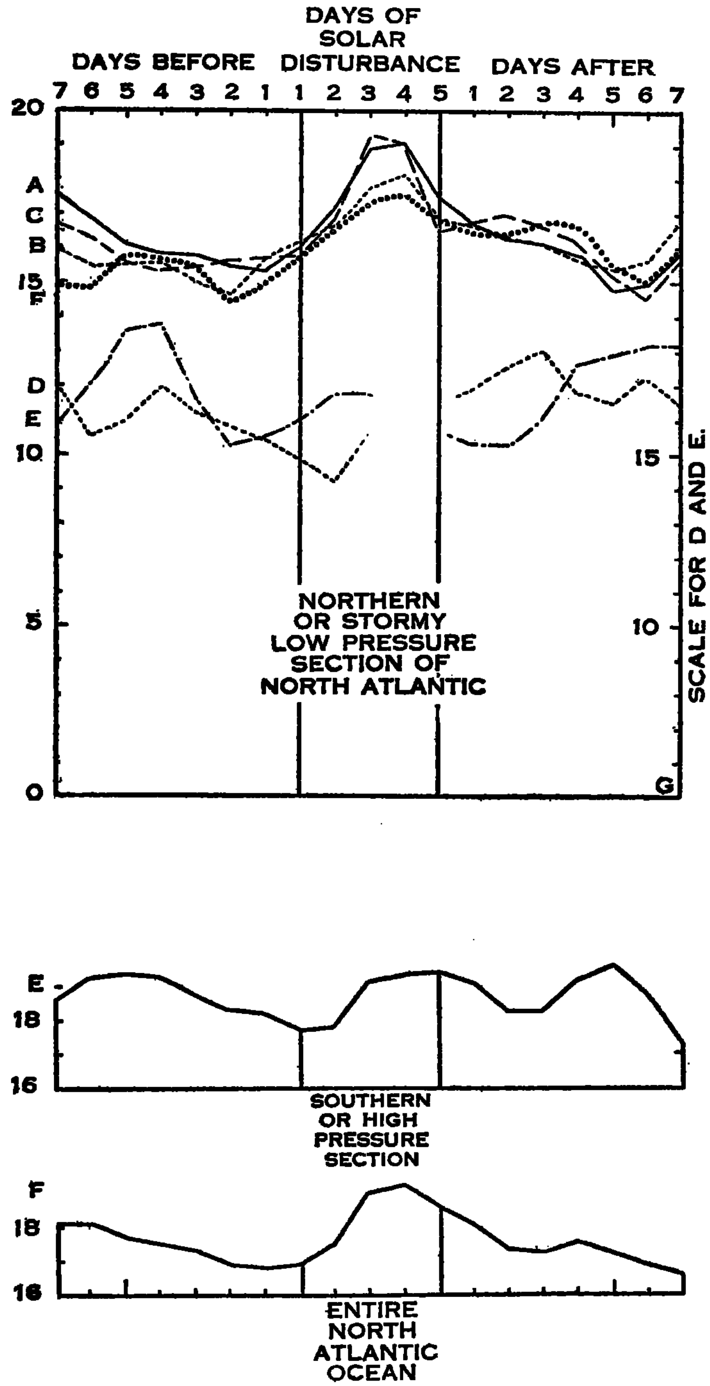
appear to influence barometric gradients. Such variations in the solar constant, however, occur on an important scale at times when there are no visible quadrant differences. Again, we are by no means sure that the quadrant differences give a full measure of the solar activity which causes barometric disturbances. As has already been indicated, the activity of sunspots is probably merely one of the more striking results of solar changes which give rise to a variety of phenomena. Among these phenomena may be included not only the solar constant, but faculæ, prominences, and magnetic variations. Most important of all, we should not expect barometric variability to fall to an extremely low ebb at times of low quadrant differences because the sun is continually changing its altitude. Even if the sun's radiation were absolutely constant, barometric variations would still occur because the angle at which the sun's rays reach the earth varies not only from hour to hour, but from season to season, and from place to place. Hence the distribution of heat upon the earth's surface constantly varies, and there must be corresponding changes in atmospheric pressure. Thus it appears that in our study of quadrant differences we are not dealing with the entire cause of variations in atmospheric pressure, but with *a hitherto unrecognized cause which appears to be superposed upon the other causes. When it is unusually strong it may temporarily outweigh the others, but when it is weak they reassert their supremacy.*

We have now reached the most critical part of our investigation. We must compare the barometric variability represented by line A in figure 10 with the variability represented by the other lines in figures 10 to 14. In order to facilitate comparison all the lines have been smoothed by the formula $\frac{1}{4}(a+2b+c)=b$. This, however, does not alter the main outlines, as may be seen from the original figures in Tables 9 and 10.

Line A in the upper part of figure 10 is based on the first part of section A of Table 9. It includes all days (138) having a quadrant difference, or solar disturbance as we may say for convenience, of over one hundred millionths of the sun's visible surface according to the Greenwich tables. In other words, when the difference between $A+D$ and $B+C$ in figure 3 [p. 125] exceeds 100, the day is included. Line A indicates that for 4 or 5 days before the beginning of a period of pronounced quadrant differences the change in barometric gradients in the stormy northern section of the North Atlantic Ocean is slight. As soon as the quadrant differences become pronounced, however, the variability of the weather increases rapidly, as appears from the upward slope of A. The variability reaches a maximum on the third or fourth day of the solar activity. This maximum is about 24 per cent greater than the minimum variability before the solar activity begins, and 29 per cent greater than the minimum on the fifth day after the end of the solar activity.

The two diagrams at the bottom of figure 10 show the the variability of the weather in the southern section of the North Atlantic and in the two sections combined. The line for the southern section is inconclusive. It rises, to be sure, at times of great quadrant differences, but it rises equally high in the periods before and after. The line for the two sections combined—that is, for the entire North Atlantic Ocean—scarcely needs comment. It shows an unmistakable maximum at times of great solar differences. For our present purposes the northern section is clearly the place of chief importance.

Let us see whether other methods of computing the solar conditions give results as striking as those already obtained. Instead of computing the solar activity by the method of differences between the outer parts of diametrically united pairs of quadrants (quadrant differences), would it be equally effective to take the periods



A, average daily change in gradient in relation to 138 periods when the area of the solar umbræ in the NW.+SE. quadrants of the sun's visible disk at a distance of over 30° from its central meridian differs from that of the similar umbræ in the NE.+SW. quadrants by 100 millionths or more of the sun's surface.

B, the same for 144 periods when umbræ on the east at a distance of over 30° from the central meridian differ from those on the west by 100 millionths or more of the sun's surface.

C, the same for 80 days which fall in both group *A* and group *B*, as described above.

Fig. 10.—Changes in barometric gradients over the North Atlantic, from day to day, in relation to solar activity.

when the difference between the marginal areas on the east and west sides of the sun (marginal differences) exceeds 100; that is, when the difference between $A+C$ and $B+D$ in figure 3 exceeds 100? This has been done in section B of Table 9, and in the dotted line B in figure 10. The method of tabulation is identical with the one described above. The number of periods of solar disturbance is essentially the same, namely, 144 instead of 138. The resultant curve is also similar, but there is an important difference. The contrast between the highest and lowest points is less than for the solid line. Where the vertical distances from the two minima to the central maximum amount to 24 and 29 per cent for the solid line A, they amount only to 23 and 18 per cent for B.[8] In fact it seems safe to conclude that the dotted line rises in the center largely because it is based in part on periods which have a quadrant difference of over 100 and hence are used in computing line A as well as line B. There are 80 such periods common to both the solid and the dotted lines. When computed by themselves, they give the dash line C. This is essentially the same as the solid line except that the minima differ from the maximum by 26 and 32 per cent instead of 24 and 29. Therefore the difference between A and B must be due to the 64 periods which have a *marginal* difference of 100 or more, but do not have a marked *quadrant* difference. That this is the case appears from line B, figure 11. In preparing this line use has been made of 34 periods which occur among the 64 mentioned above, but do not come within two days of periods having quadrant differences of 100 or more, and hence have small quadrant differences. The central dip of the line for these 34 periods suggests that when there is little or no quadrant difference, a marginal difference between the opposite sides of the sun's disk does not have a marked effect upon the barometric gradients of the northern section of the North Atlantic Ocean.

Let us see whether contrasts between the spottedness of the outer 60° of the sun's northern and southern hemispheres is any more important than a contrast betwsen the east and west margins. This matter is tested in section D of Table 9. This is based on 53 periods which have a difference of 100 or more between the north and the south; that is between $A+B$ and $C+D$, figure 3, but have quadrant differences of less than 100. In other words, these periods had a strong difference between north and south, but not between the marginal portions of the diametrically paired quadrants, $A+D$ and $B+C$, figure 3. The way in which they were related to barometric changes is shown in line D, figure 10. The zero for this line, as well as for line E, has been lowered to prevent crowding. Line D is low during the critical period of solar disturbance, but rises fairly high immediately afterward. This suggests that a difference between the spottedness on the two sides of the sun's equator may possibly have some effect on the earth's atmosphere, but that, like marginal differences, it is not nearly so important as quadrant differences.

As still another means of testing our conclusions let us see what happens when there are abundant spots on *both* the east and west margins of the sun, so that the two sides balance one another. This is done in section E Table 9, and in the dot-and-dash line E, in figure 10. This line is based on 79 periods when the umbral area of the sun spots in the marginal 60° of the sun, taking east and west together, amounted to 100 or over, but when the quadrant differences did not exceed 50; such periods usually last only a day. About a quarter of them last two days, and a tenth three or four. Their curve is wholly different from lines A to C above it. It has two main maxima almost where the others have minima. The slight maximum in the center is apparently due to the fact that while we have excluded all days with a quadrant difference of above 50, we have not excluded those with a smaller quadrant difference. The days employed for line E are bound to have these small quadrant differences. Hence, there is likely to be a slight increase of storminess. The essential point of the whole matter is that a great abundance of spots on the margins of the sun does not seem to affect the weather unless the spots are so arranged that there is an excess in one particular quadrant.

In order that our tests may be as varied as possible, let us next see what happens when the sun spots in the marginal 60° of a given quadrant have an umbral area which exceeds that of the corresponding quadrant on the same side of the equator, by 100 or more. The results appear in sections A to D of Table 11 (p. 176), and in the four broken lines, A to D, of figure 13. Line A represents barometric changes in the northern section of the North Atlantic Ocean in relation to 39 periods when the umbral areas in the marginal part of the sun's northwestern quadrant exceeded the areas in the corresponding part of the northeast quadrant by 100 or more. The other lines represent similar conditions for each quadrant. It may be remarked in passing that as a rule the sun is not active in more than one quadrant at a time. For example, among the 148 periods used in preparing lines A to D only 30 are characterized by umbral areas of more than 100 in the marginal 60° of two quadrants at the same time. During the 10 years under consideration there was not a single instance of umbral areas exceeding 100 in the marginal 60° of three quadrants at the same time.

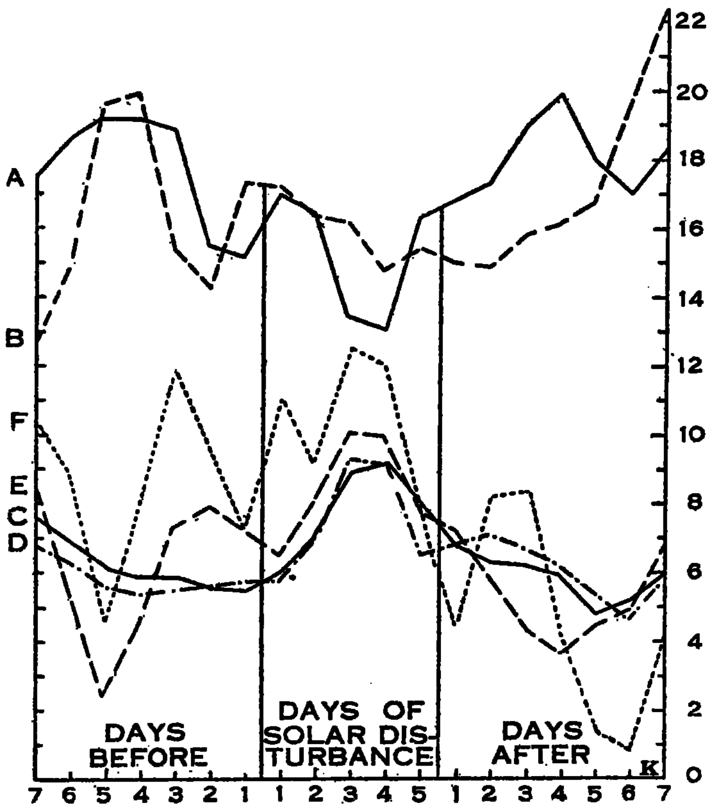
The interpretation of lines A to D in figure 13 is obvious. The two, A and B, which represent the sun's northern hemisphere, rise strongly during the times of their respective solar disturbances and reach a maximum

TABLE 10.—*Changes in barometric gradients in northern section of North Atlantic in reference to periods when a given group of sunspots produced a large quadrant difference on both margins of the sun, 1904–1913. (See figure 11, curve A.)*

	8	7	6	5	4	3	2	1	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
SOUTH.																												
Average change	15.0	14.1	26.1	13.8	12.5	14.2	14.9	17.0	15.2	21.2	21.6	15.4	18.9	13.7	16.2	11.5	11.4	13.3	13.5	11.9	18.3	14.2	23.0	17.2	22.8	19.4	17.6	25.2
Sm. average	.....	17.3	20.0	16.6	13.3	14.0	15.3	16.0	17.2	19.8	20.0	17.6	16.8	15.6	14.4	12.6	11.9	12.8	13.0	14.0	15.7	17.4	19.3	20.1	20.6	19.0	20.0	....
NORTH.																												
Average change	20.7	20.5	15.6	10.9	15.8	16.9	18.1	14.5	18.3	13.3	20.1	16.9	22.0	14.9	20.6	16.5	15.7	14.7	19.5	16.6	16.9	13.8	22.7	14.1	13.5	9.8	14.0	17.1
Sm. average	.....	17.6	15.6	13.3	14.8	16.9	16.9	16.4	16.1	16.3	17.6	18.9	18.9	18.1	18.2	17.3	15.7	16.2	17.6	17.4	16.1	16.8	18.3	16.1	12.7	11.8	13.7	....
Total north and south sm. average change	.....	18.3	17.8	14.9	14.0	15.4	16.1	16.2	16.6	18.0	18.8	18.4	17.9	16.9	16.3	15.0	13.8	14.5	15.3	15.6	15.9	17.1	18.9	18.1	16.6	15.8	16.8	....

[8] In figure 10 the line F, marked by circles, shows still another way of testing our results. The line is computed in the same way as line B, but instead of taking the eastern and the western margins of the sun as units each margin is divided into a northern and a southern half. Then the difference between the east and west sides in the northern half is computed, and likewise the difference in the southern, and the two are added. This gives 148 periods instead of 144. The difference between the minima and the maximum amounts to 22 per cent and 17 per cent. Thus this method indicates less relationship than the one employed in the text.

on the third or fourth day, just as does the solid line A, in figure 10. Lines C and D, showing the relation of barometric changes to the sun's southern hemisphere, are similar to A and B, but rise less rapidly and markedly and reach their maxima later. In other words, an abundance of spots on the sun's margin has the same kind of effect no matter in which quadrant it is located. During the years 1904–1913, however, the effects produced by the southern solar hemisphere were less pronounced and less immediate than those of the northern. This accords with the fact that the days on which the southern figures are based had more than 50 per cent less solar activity than those of the northern figures.



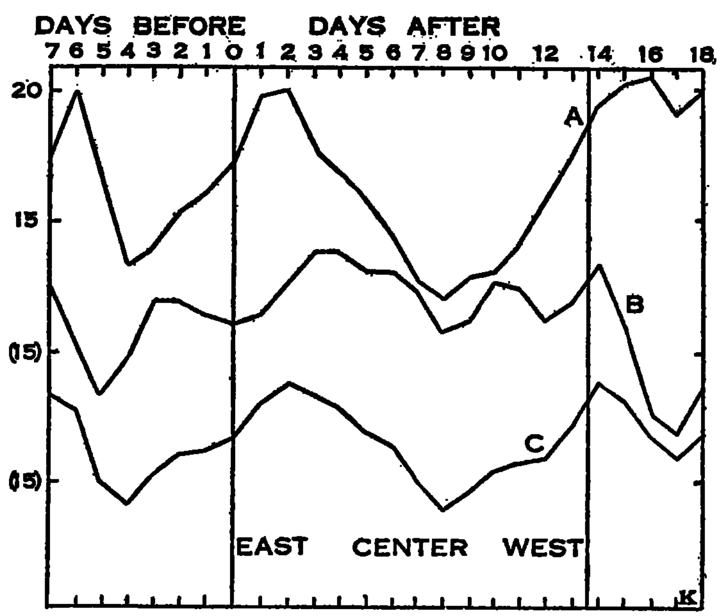
C and *D* are the same as in figure 10, *A* and *C*.
E, based on 25 days in 1904–1913, of highest quadrant differences.
F, based on the 10 days of very highest differences.

FIG. 11.—The degree of variability of the weather in the northern section of the North Atlantic at times of high quadrant differences.

In similar fashion in figure 13 the two dotted lines which pertain to the sun's eastern margin rise higher than the dash lines pertaining to the western margin. This suggests that spots on the eastern side are more important than on the western. It is opposed to the indications already discussed in relation to Table 1 and figure 4. Since these apparent differences seem to balance one another, they are probably due to chance. Apparently all four of the sun's quadrants are equally effective.

In analyzing the relation of the sun to terrestrial weather many puzzling results are found. In some cases the results of a given set of solar conditions may easily be confused with those of other allied conditions. For example, section E of Table 11 and line E in figure 13 seem to indicate the strongest kind of relationship between the earth and the sun. The maximum of the smoothed curve lies 145 per cent above the minimum that precedes it and 102 per cent above the succeeding minimum. This line is based on 14 periods showing a difference of 100 or more between the umbral areas on the east and west sides of the sun in both the northern and southern solar hemispheres.[4] When we use this same method on a larger scale, however, as is done in line F, figure 10, it does not give nearly so pronounced a result as the method of quadrant differences. The 14 periods used for line E, figure 13, are accompanied by quadrant differences averaging 122, so that these, rather than the contrast between the east and west sides, may be the cause of the apparent relationship.

Further confirmation of this conclusion is found in the four lower lines of figure 11. All of the lines represent the degree of variability of the weather in the northern section of the North Atlantic at times of high quadrant differences. Lines C and D are the same as A and C in figure 10. Line C shows the conditions in relation to 138 days having quadrant differences of over 100. Line D is based on 80 days on which the quadrant differences were a little more pronounced. Accordingly, C rises a little higher than A during the time of solar disturbance and falls a little lower 6 days afterwards. Line E is based on the 25 days during the period 1904–1913 showing the highest quadrant differences, while line F is based on the 10 days when the quadrant differences were highest of all.[5] The most significant fact about these four lines is the way in which the interval between the maximum during the time of solar disturbance and the succeeding minimum increases with the increase in the



A, southern groups. *B*, northern groups. *C*, both groups combined.

FIG. 12.—Effect of sunspot groups as they pass from the eastern to the western margin of the sun (compare Table 10).

[4] The dates of these periods are as follows:
1906: June 28, July 7, Aug. 3, Dec. 15, Dec. 22–24.
1907: Feb. 26-27, May 12.
1908: Aug. 9-10, Aug. 25–28, Sept. 12–15.
1909: Jan. 25-27, Feb. 25, Mar. 4–6, Nov. 30, Dec. 2.
Line F in figure 13, based on F in Table 10, shows the variation in the actual strength of the gradients in the northern section of the North Atlantic for these same dates. We have said little about the gradients themselves, but in general their steepness is closely proportional to their change from day to day.

[5] The first days of these periods are as follows:
(A) 10 periods with largest quadrant differences:
1905: Jan. 29, July 19.
1907: Feb. 11, June 14, Sept. 27, Oct. 15, Nov. 17.
1908: Sept. 2.
1909: May 7, Sept. 10.
(B) 15 periods with next largest quadrant differences:
1904: Oct. 29, Dec. 7.
1905: Oct. 14, Dec. 22.
1906: July 7, July 29.
1907: June 22, July 12, Oct. 23, Nov. 9.
1908: Nov. 13, Dec. 27.
1909: Nov. 30.
1910: Feb. 25, Sept. 27

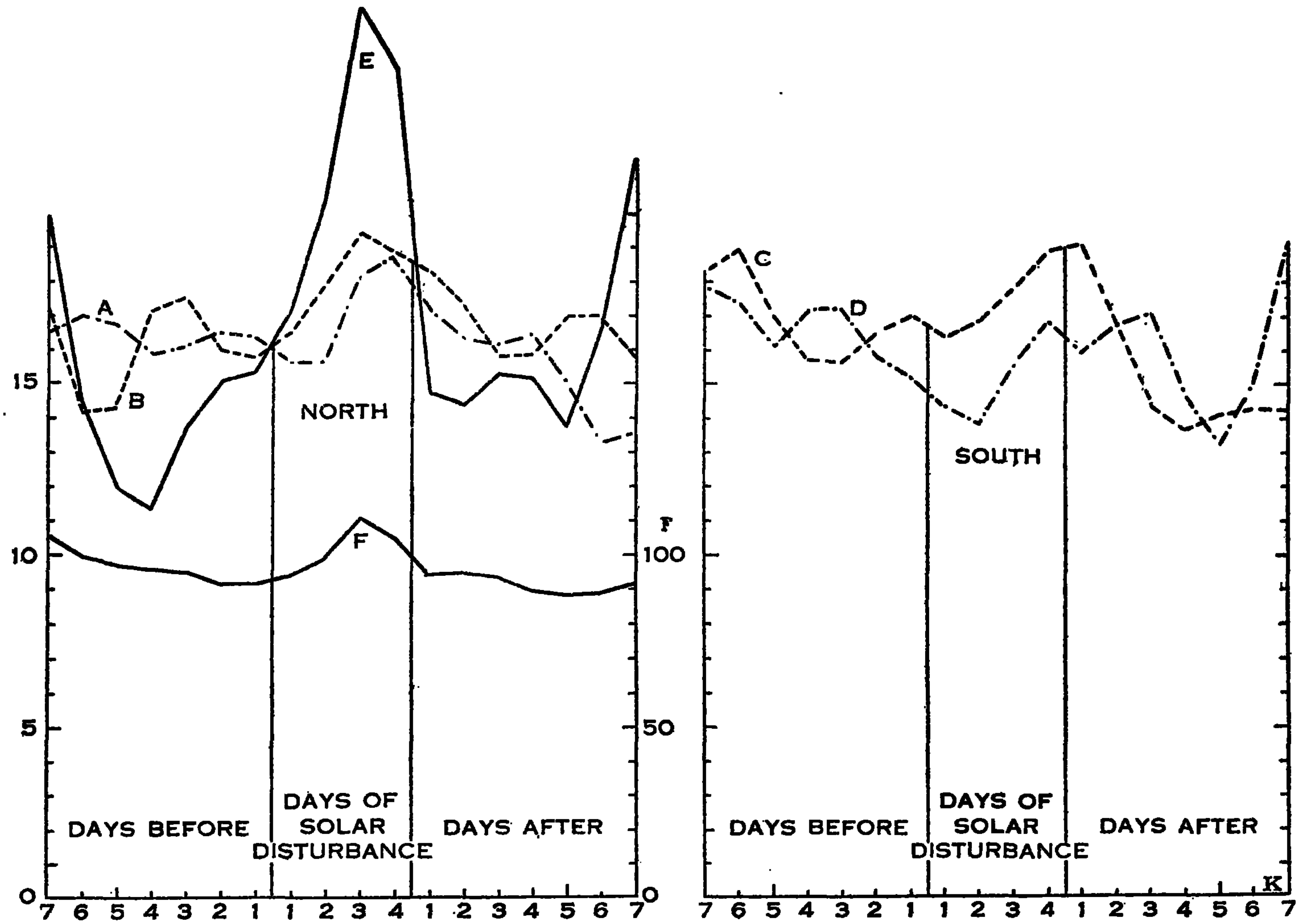
quadrant differences. In tabular form this may be expressed as follows:

	Per cent.
(1) Highest 138 days	29
(2) Highest 80 days	32
(3) Highest 25 days	47
(4) Highest 10 days	106

The rapidity with which these percentages increase is highly significant. So, too, is the low level to which the change in gradients falls at the minima representing the times when this particular type of solar effect is slight, either because of the absence of spots or because the spots are concentrated near the sun's center. *Apparently when the quadrant differences or the accompanying weather-producing agencies of the sun's surface are particularly active, the North Atlantic Ocean alternates rapidly between periods of low gradients accompanied by remarkably little change of weather and periods of high gradients accompanied by storms.*

The truth of this conclusion may be illustrated in another way, as is seen in figure 12. Here 20 sunspot groups have been selected, because they gave rise to large quadrant differences when they appeared on the sun's eastern margin and again when they disappeared on the western margin. Ten of these groups were in the sun's northern hemisphere and 10 in the southern. The change in barometric gradients in the northern section of the North Atlantic Ocean in respect to each of these periods appears in Table 10 and is plotted in figure 12. The day marked 0 is the day on which the solar disturbances first became evident, and thereby caused large quadrant differences. When spots were abundant in the southern hemisphere, line *A*, the gradients rose to a maximum within one or two days after the quadrant differences became high. Six days later, when the spots were near the sun's center, the change in barometric gradients fell very low, and the weather was comparatively steady. After another eight days the weather again became disturbed, and this disturbance apparently was connected with the quadrant difference caused by the presence of spots on the sun's western margin. The interval from one maximum to the other in this case is 14 days. It suggests that the maximum effect is produced when the spots are almost on the sun's limb.

Line *B*, figure 12, suggests that spots in the northern hemisphere have less effect than those in the southern. During the periods on which it is based the average intensity of the quadrant differences in the northern



A, northwest greater than northeast.
B, northeast greater than northwest.
C, southeast greater than southwest.
D, southwest greater than southeast.
E, 14 periods showing a difference of approximately 100 or more, between the eastern and western margins both north and south of the solar equator.
F, resembles *E*, but is for gradients instead of changes in gradients.

FIG. 13.—Changes in barometric gradient from day to day in the northern section of the North Atlantic, in relation to periods when the areas of solar umbræ in the marginal 60° of one solar quadrant exceed those of the opposite quadrant on the same side of the solar equator by 100 millionths or more of the sun's surface (compare Table 11).

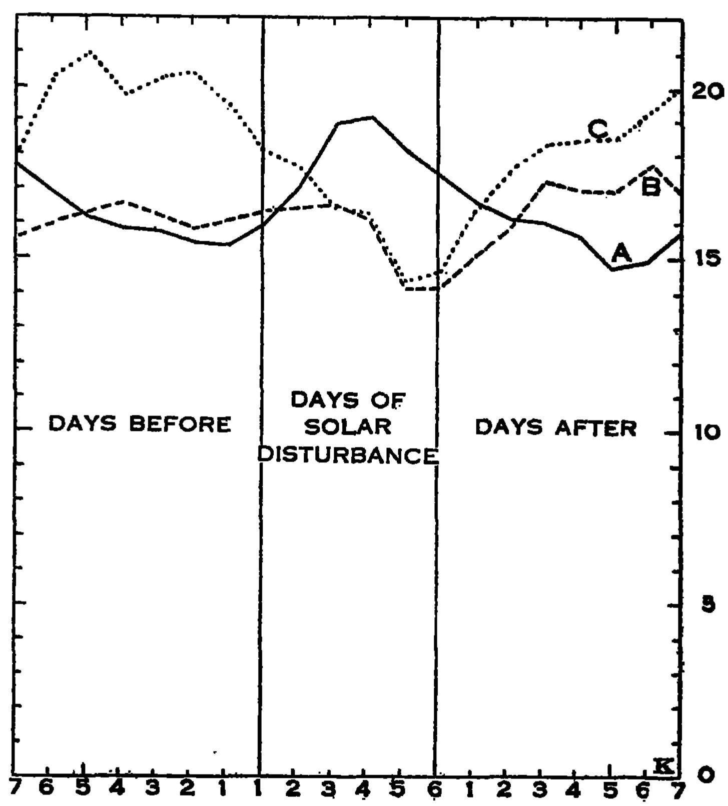
TABLE 11.—*Changes in barometric gradients in northern section of North Atlantic in relation to days having a difference of over 100 in umbral areas within 60° of sun's margin on opposite sides of the northern and southern hemispheres (see fig. 12).*

	Days before.								Days of solar difference.								Days after.							
	8	7	6	5	4	3	2	1	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8
A.—NW. EXCEEDS NE. BY 100 OR MORE.																								
Number of days	35	36	36	36	36	36	37	37	39	30	22	14	6	......	......	......	39	38	38	37	36	36	36	35
Average change of gradients	15.9	16.5	17.0	17.5	14.9	16.4	16.6	16.5	16.0	13.6	20.3	18.8	22.2	......	......	......	16.7	16.7	15.3	17.5	15.6	11.6	14.5	13.7
B.—NE. EXCEEDS NW. BY 100 OR MORE.																								
Number of days	26	26	27	27	27	27	27	27	30	26	20	15	2	1	......	......	30	30	30	28	27	27	26	26
Average change of gradients	18.3	19.5	12.1	13.4	18.9	17.6	16.1	14.5	17.8	15.5	23.7	15.3			......	......	19.7	17.4	14.9	16.1	16.6	18.7	14.1	16.2
C.—SW. EXCEEDS SE. BY 100 OR MORE.																								
Number of days	34	35	35	36	38	38	38	39	44	31	21	13	5	2	2	......	44	43	41	40	37	36	35	35
Average change of gradients	15.5	17.9	19.6	12.6	19.6	16.9	15.5	15.5	14.5	12.2	16.7	18.7	18.9			......	15.2	16.1	19.8	12.4	14.1	12.1	22.3	20.2
D.—SE. EXCEEDS SW. BY 100 OR MORE.																								
Number of days	29	29	29	29	31	31	31	32	32	25	22	17	5	......	......	......	32	32	32	32	30	29	29	29
Average change of gradients	17.6	16.6	22.4	14.2	17.2	14.3	16.9	17.9	15.2	17.4	18.0	17.7		......	......	......	21.0	16.4	13.9	13.3	14.4	14.7	13.2	15.8
E.—SE. EXCEEDS SW., AND NE. EXCEEDS NW., BY OVER 100; OR ELSE SW. AND NW. EXCEED SE. AND NE., RESPECTIVELY, BY OVER 100.																								
Number of days	10	10	11	11	12	12	14	14	14	8	6	3	......	......	......	......	14	14	14	14	10	10	10	10
Average change of gradients	21.7	23.6	11.3	15.2	6.2	17.8	13.4	15.9	16.0	22.4	30.0	25.0	......	......	......	......	14.2	13.6	16.3	15.1	13.6	12.4	27.8	18.1
F.—SAME AS "E," BUT GIVING ACTUAL GRADIENT INDICES INSTEAD OF CHANGES.																								
Number of days	10	11	11	11	12	12	14	14	14	8	5	3	......	......	......	......	14	14	14	14	11	11	11	10
Average of actual gradients	105.4	108.4	95.0	101.0	91.0	99.8	88.8	91.5	95.0	96.5	115.6	131.0	......	......	......	......	89.3	96.0	96.1	85.7	88.9	89.1	90.0	97.1

hemisphere was 80 per cent greater than for the similar periods of the southern hemisphere. Yet *B* is far less regular than *A*. Nevertheless it has a maximum 3 or 4 days after the quadrant differences become large, a minimum when the spots are near the sun's center, and a less pronounced maximum 11 days after the first one. The average of the two lines with its maxima on the 2d and 14th days after the quadrant disturbances become large, and its minimum half way between them affords strong confirmation of our conclusion that when sun spots are located on the sun's margin, stormy weather prevails in the North Atlantic Ocean, whereas when they are near the center of the sun's disk they are accompanied by relatively little change of weather.

Comparison between sunspots in the sun's center and barometric gradients.

Before leaving this part of our subject, let us turn from the sun's margin to its center. It will be recalled that stormy periods seem to occur at times when there are few spots in the central portion of the sun's disk. Let us now take the part of the sun within 30° of the central meridian and see how it is related to variability of the weather in the two sections of the North Atlantic. This is illustrated in lines *B* and *C*, figure 14, which are based on section *C* in Table 9. The solid line *A*, is the same as *A* in figure 10. The only difference is that here the 6th, 7th, and 8th days of solar disturbance have been separated from the 5th, thus increasing the width of the central section of the diagram. The other lines represent the degree of variation of the gradients from day to day in the northern section of the North Atlantic Ocean, *B*, and in the southern section, *C*, in relation to 110 periods when the umbral areas within 30° of the sun's central meridian amounted to 100 or more. Both



A, average daily change in gradient over the northern section of the ocean in relation to 133 periods when the area of the solar umbræ in the NW.+SE. quadrants of the sun visible disk at a distance of over 30° from the central meridian, differed from the area from the similarly located umbræ in the NS.+SW. quadrants by 100 millionths or more of the sun's visible area.

B, the same in relation to 110 periods with umbral areas of 100 millionths or more, within 30° of the central meridian.

C, the same as *B*, but for the southern section of the North Atlantic Ocean.

FIG. 14.—Changes in barometric gradients from day to day over the North Atlanti Ocean, in relation to solar activity (Table 9 *C*).

B and *C* take a marked drop at times when spots continue to be abundant in the sun's central area for 4 or 5 days. In the south, *C*, however, the drop is far more marked and begins earlier than in the north, *B*. The reversal between *C* and *A* is striking. It serves strongly to reenforce the idea that *storminess accompanies a lack of balance among the sun spots in the marginal portions of the sun, while quiet weather free from storms occurs when a balanced condition is produced either by the absence of disturbed areas on the sun's surface or by the concentration of such areas in the sun's center.*

(To be continued.)

CHANGES IN OCEANIC AND ATMOSPHERIC TEMPERATURES AND THEIR RELATION TO CHANGES IN THE SUN'S ACTIVITY.[1]

By Professor FRIDTJOF NANSEN, University of Kristiania.

[*Author's abstract* reprinted from Jour., Wash. Acad. Sci., Mar. 4, 1918, 8: 135-138.]

The primary aim of the research was to find the relations existing between oceanic and atmospheric temperatures. The surface temperature of the water in various parts of the North Atlantic at the coldest time of the year formed the foundation of the first study. When the region covered by the data is divided into approximately equal areas, the temperature curves of these areas are found to be parallel, it is evident from the form of the curves that these changes of temperature, taken as a whole, are not due to changes in the water-masses transported. A relation does appear, however, between these changes and the prevailing direction of the wind, as deduced from atmospheric pressure gradients. Where the wind turns south of (i. e., is directed south of) its average direction over a period of years, the temperature of the water is lower than the average for the same period, and vice versa. A similar parallelism between wind direction and water temperature appears along the coast of Norway; the effect near the coast is based on the direction of the wind with respect to the land, as well as on the season of the year. The air temperature variations on land appear earlier than the variations in water temperature.

Certain periodicities appear in all the curves of oceanic and atmospheric temperatures, but they vary in type. At the same time a relation also appears between these curves and curves of sun-spot activity and magnetic elements. The 11-year period is prominent. An oceanic type and a continental (Eurasian) type can be distinguished. The latter follows the sunspot curve directly, whereas the former type follows the sunspots inversely. There is also a third and very remarkable type in which the curve changes more or less suddenly from direct to inverse. This sudden inversion is brought out in many curves, comparing stations in different parts of the earth, and the inversion occurs in very many cases at about the year 1896.

When the temperature curves for different months of the year are compared with the sunspot curves, these three types of agreement again appear in very puzzling and unexpected combinations.

In addition to oceanic and atmospheric temperatures, other meteorological elements (air pressure, wind velocity, rainfall, cloudiness, mean daily temperature-amplitude) show a relation to the sunspots, sun prominences, and magnetic variations, and show not only the 11-year period, but also shorter periods of two, three, and five and one-half years.

The fluctuations of the temperature at the earth's surface do not follow directly the variations in the energy received from the sun as determined by the measurements of Abbot and Fowle. The daily and yearly temperature-amplitudes are believed to furnish sufficient refutation of hypotheses based on supposed variations in the absorbing and reflecting power of the atmosphere, as well as of Humphreys' hypotheses as to formation of ozone or effects of volcanic dust. Blandford's hypothesis of the effect of increased evaporation in lowering continental temperatures at sunspot maxima is also not supported by the facts of tropical land and ocean stations.

The mistake of most authors when they have discussed the causes of temperature changes, has been that they took for granted that the average temperature at the earth's surface was directly dependent on solar radiation, and would give a direct indication of heat received. They have not considered sufficiently the fact that a very great proportion of the sun's radiation is absorbed by the higher layers of our atmosphere and that the distribution of heat in the atmosphere is of the greatest importance for the temperatures at the earth's surface. They seem very often to have forgotten that the variations in the sun's activity, and in the so-called "solar constant," and also in the sun's electric radiation, may primarily influence the higher layers of the atmosphere, thus indirectly guiding the distribution of atmospheric pressure and the circulation not only of these higher layers, but also of the lower parts of the atmosphere. In this manner the temperature of the higher latitudes may be influenced more than that of the Tropics where the conditions are so stable.

The variation in *pressure gradient* seems much more closely related to the temperature of land stations than is the variation in air pressure itself. For instance, the Colombo-Hyderabad gradient runs parallel to the temperature in the Himalayas but opposite to the temperature at Batavia, while Bombay forms an example of those strange reversals occurring about 1896. The Iceland-Azores gradient has exactly opposite effects in Norway and in mid-Atlantic. An increase of air circulation may thus have opposite effects in different regions. The sunspots and magnetic elements sometimes oppose and sometimes agree with the variations in pressure gradients.

Various periodicities appear in the sunspots as well as in the terrestrial phenomena. In the sunspots there is an 8-month period corresponding with the conjunction or opposition of the planets Venus and Jupiter with the sun. This same period occurs in the North Atlantic gradient, and was found by Krogness in the magnetic declination at Kristiania. There are also periods of six and twelve months in the magnetic elements, due to the position of the earth. The combination of these 6-, 8-, and 12-month periods gives a 2-year period for the magnetic and meteorological elements on the earth. But in the fluctuations of the sunspots a similar period of two years is also discovered, and specially noticeable are indications of minima every second year. Before 1896 there is an agreement between the 2-year minima of temperature at certain stations and the corresponding sunspot minima, but the agreement is remarkable in that the greatest depressions in the sunspot curve

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[1] Illustrated review, before the Washington Academy of Sciences, Jan. 8, 1918, of the recent book.

Helland-Hansen, Bjørn, & Nansen, Fridtjof. Temperatur-Schwankungen des Nordatlantischen Ozeans und in der Atmosphäre. Einleitende Studien über die Ursachen der klimatologischen Schwankungen. Videnskapsselskapets Skrifter, I Mat.-naturv. Kl., 1916, No. 9. Kristiania, 1917. [viii, 341 p. charts. tables. 27½ cm.] This work is now in the Weather Bureau library.